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Percent Accuracy by Crown Closure Classes of Woodland Stands Mapped from Skylab-4 Photography and Landsat-1 Imagery

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APPROVED:

(Thesis Director)

Dean of the Graduate School

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PERCENT ACCURACY BY CROWN CLOSURE CLASSES OF WOODLAND STANDS MAPPED FROM SKYLAB-4 PHOTOGRAPHY AND LANDSAT-1 IMAGERY

by

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In Partial Fulfillment

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INTRODUCTION

On July 23, 1973, the Land Satellite[1] (LANDSAT-1) was launched into a sun synchronous polar orbit around the Earth at an altitude of 911 km. The satellite was designed to sense the Earth's environment on an 18-day reptitive cycle. LANDSAT-1 has two types of imaging sensors:

1. Multispectral Scanner, and
2. Return Beam Vidicon Cameras.

On August 15, 1972, the Return Beam Vidicon Cameras were rendered inoperative due to functional problems.

The Multispectral Scanner produces four synchronous images of four different wave bands. The wave-length ranges of each band are:

1.	Band 4 (green)	0.5 to 0.6 micron
2.	Band 5 (lower red)	0.6 to 0.7 micron
3.	Band 6 (upper red- lower infrared)	0.7 to 0.8 micron
4.	Band 7 (infrared)	0.8 to 1.1 micron

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[1]LANDSAT-1 was formerly designated Earth Resources Technology Satellite (ERTS-1).

Each band produces an image that contains an area of approximately 185 by 185 km on the ground.

The Skylab Orbital Workshop was launched in April, 1973, into an orbit at an inclination of 50° to the equator at an altitude of 435 km. The Skylab crews occupied the workshop from May 25, 1973 thru June 22, 1973 (Skylab 2), July 28, 1973 thru September 25, 1973 (Skylab 3), and November 16, 1973 thru February 8, 1974 (Skylab 4). The Skylab Orbital Workshop had many experiments, but the one utilized in this thesis was the Earth Resources Experiment Package (EREP).

The EREP consisted of six systems to sense the Earth. These were:

1. Multispectral Camera (Provided high-resolution photographs),
2. Earth Terrain Camera (Provided high-resolution photographs),
3. Infrared Spectrometer (Provided data to remove atmospheric effects from multispectral scanner data),
4. Multispectral Scanner (Provided data received at the same frequencies by multispectral photographic facility for spectral pattern recognition and discrimination studies and for comparison

with results of photointerpretation),

5. Microwave Radiometer, Scatterometer, and Altimeter (Provided dielectric properties of sites recorded by other sensors to enhance data interpretation), and
6. L-Band Radiometer (Provided dielectric properties of sites recorded by other sensors and permitted corrections for atmosperic water-vapor effects on microwave radiometer, scatterometer, and altimeter) (Anonymous, 1974).

Photography from the multispectral camera system was used for this study.

The Multispectral Camera system consisted of six high-precision cameras with matched optical units mounted and boresighted to photograph the same area on the Earth simultaneously. The six cameras sensed at the following wave-lengths:

Station 1.	0.7 to 0.8 micron,
Station 2.	0.8 to 0.9 micron,
Station 3.	0.5 to 0.88 micron,
Station 4.	0.4 to 0.7 micron,
Station 5.	0.6 to 0.7 micron, and
Station 6.	0.5 to 0.6 micron.

Each camera produced photographs that covered an area of 163 to 163 km on the Earth's surface.

Several studies have utilized LANDSAT-1 imagery for mapping forests and woodlands and determining land uses. Skylab photography has not been used for this purpose because it has become available only recently. This study went one step farther by determining the percent accuracy by crown closure classes for woodland stands mapped from Skylab-4 photography and LANDSAT-1 imagery. The purpose of the study was to determine the accuracy of crown closure classes of woodland stands on both Skylab-4 color infrared photographs and LANDSAT-1 color infrared composite imagery. This determination can be used to evaluate the relative success of mapping woodlands from space imagery and photography.

LITERATURE REVIEW

Photographic interpreters have encountered many problems in the delineation of woodlands from LANDSAT-1 imagery. These problems include the need for special training for interpretation, acquiring cloud free coverage, orthographic displacement of forest stands, and inconsistent tones of similar images (Heller, 1973).

In spite of these difficulties, LANDSAT-1 has the potential to be a useful tool for foresters. Studies have shown that Band 5 (Red, 0.6 - 0.7 micron) and Band 7 (near infrared, 0.8 - 1.1 micron) when used on an optical combiner are best for identifying vegetation. For single band interpretation, Band 5 is best to study vegetation, while water bodies, river and streams are most visible on Band 7 (Heller, 1973).

In the temperate zones, the greatest contrast in forest vegetation is shown on spring, fall, and winter LANDSAT-1 imagery. In semiarid regions, summer imagery shows greater contrast between woodlands and open areas when most of the rainfall occurred in the previous winter (Heller, 1973). Forests can be separated from non-forest land when trees are young to mature in age but differentiation is troublesome when forest are in a transitional state, such as recently planted stands.

At the Johnson Space Center (JSC) in Houston, Texas, an evalution of LANDSAT-1 imagery was conducted to determine the practicality and validity of LANDSAT-1 in classifying forests stands and related land-use features. The objectives of the JSC study were (1) to determine the size of the forest features which could be detected using LANDSAT-1 imagery under varying conditions, (2) to determine the suitability of these data for making forest classification maps, (3) to test the extension of feature classification from one area to another, and (4) to evaluate the accuracy of LANDSAT-1 data in forest application (Erb, 1974). To determine if these goals were achieved, the approach was (1) to study the detection capabilities, and (2) the various conventional imagery interpretation and computer processing methods for LANDSAT-1 data (Erb, 1974).

The accuracy for the various methods was:

1. Single band conventional classification (67 percent)
2. Optical multiband classification (60 percent)
3. Multichannel Film Viewer (69 percent)
4. JSC Color Composite (67 percent)
5. Large-area cluster (computer) classification (74 percent)

6. Small-area cluster (computer) classification (74 percent)
7. Maximum-likelihood classification (70 percent)
8. Earth Resources Interactive Processing System classification (61 percent).

These accuracies were determined by comparing ground truth maps made from aircraft photography of April, October, and November of 1972. These maps were supplemented by ground checks (Erb, 1974).

LANDSAT-1 data can best be used in forest application when applied to an extensive survey which utilizes a broad generalized classification; however, it is inadquate for an intensive survey which requires detail stand information. The clustering and maximum-likelihood methods of computer classification techniques were determined to be efficient in classifying forest land-uses (Erb, 1974).

LANDSAT-1 data have been used with low altitude photography and ground measurements in a multistage sampling technique to estimate timber volume on the Quincy Ranger District of the Plumas National Forest in California (Nichols, 1974). LANDSAT-1 analysis was conducted using both manual and automatic analysis techniques with classification of volume based on four volume classes: (1) non-forest, (2) forest sites with less than 10 MBF per acre,

(3) forest sites with 10 - 20 MBF per acre, and (4) forest sites with more than 20 MBF per acre. The sampling error of this volume estimate was 8.2 percent which was below the expected sampling error of 20 percent (Nichols, 1974).

DeSteiguer (1974) used Skylab photography at a scale of 1:500,000 and LANDSAT-1 imagery at a scale of 1:250,000 to map forest types in the Atchafalaya River Basin. The accuracy achieved with the forest type maps were 66.7 percent for Skylab photography and 60.7 percent for LANDSAT-1 imagery.

Space photography has been used to map forest resources on the Atlanta, Georgia, test site with over 96 percent accuracy in separating forest land from non-forest using color infrared photography taken in the fall or winter months. The major problem with microscale photography (a scale generally less than 1:125,000) was that species groups were not easily separable (Aldrich and Greentree, 1972).

Justification

LANDSAT-1 imagery and Skylab photography used to map woodland stands and land-uses appears to have value, but study of the literature revealed no research conducted to determine correlation between mapped stands and their crown closure. Knowledge of the relationship between mapped stands and crown closure will allow others to determine if

LANDSAT-1 imagery or Skylab photography will be applicable to their needs under situations where percent accuracy of crown closure and/or minimum crown closure mapped is needed.

PROCEDURE

The procedure for this study was designed to establish the accuracy by stand density for woodland stands mapped from Skylab-4 photography and LANDSAT-1 imagery. Crown closure was used to estimate stand density because the tree crowns are the primary area sensed. Crown closure classes have been used by photointerpreters to estimate stand density for at least two decades. Crown closure can be estimated best from aerial photographs (Spurr, 1960).

Previous researchers have used high altitude photography successfully to map woodlands with a low percent error. This study used a new source, space photography and imagery, to map woodland areas. The results of this mapping was checked by an old technique (crown closure estimation from large scale aerial photography) and a proven new technique (woodlands mapping from high altitude photography).

This background knowledge was used to develop a prototype process to establish a quantitative value for the woodlands stands mapped. This process will be of importance in the future because LANDSAT-1 imagery will be used to provide a base for a national vegetation cover and continuous land classification inventory (Anderson, 1975).

Study area

The study area was Burleson and Washington Counties, Texas (Appendix 1) where the woodlands consisted primarily of post oak (*Quercus stellata*). The area was selected for the following reasons:

1. It was similar to a portion of the Red River Basin above Denison Dam on which the woodlands were being mapped for the Forest Service, Department of Agriculture.
2. Land-use maps were available for the area.
3. NASA high altitude color infrared photography was available.

Remotely sensed data

Two types of remotely sensed data were used:

1. Skylab-4 Multispectral Camera system photography
2. LANDSAT-1 imagery

The Skylab-4 photography was taken on January 20, 1974, with color infrared ($0.5 - 0.88\mu$) EK 2443 Film[2]. The format of the Skylab photography was a 65.15 by 65.15 cm,

[2]The Skylab photography was Skylab-4 mag 75 frame 372.

1:250,000 scale paper print. The LANDSAT-1 imagery used was a color composite of Bands 5 (0.6 - 0.7μ) and 6 (0.7 - 0.8μ) taken on May 9, 1973[3]. The format of the imagery was a 74.17 by 74.17 cm, 1:250,000 scale paper print.

The Skylab-4 color infrared photograph showed woodlands, lakes, streams, roads, and other land-uses. The woodlands appeared dark brown to black in tone. This tonal characteristic was the primary factor used for interpreting areas as woodlands. Secondary factors used to confirm the interpretation were shape, texture, and size (Figure 1, 2).

LANDSAT-1 color infrared composite showed less detail which made the interpretation more difficult to accomplish. Woodlands appear as a reddish brown tone and water appears as a blue tone (Figure 3, 4). Because of extensive flooding in some woodland areas, accurate interpretation was impeded.

Interpretation

The areas in Burleson and Washington Counties, Texas considered to be woodlands were first mapped using the Skylab-4 photograph and then the LANDSAT-1 color composite imagery. There was approximately a month interval between the delination of woodlands on each frame to reduce human

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[3]The LANDSAT-1 imagery number was 81452162845G200-C.

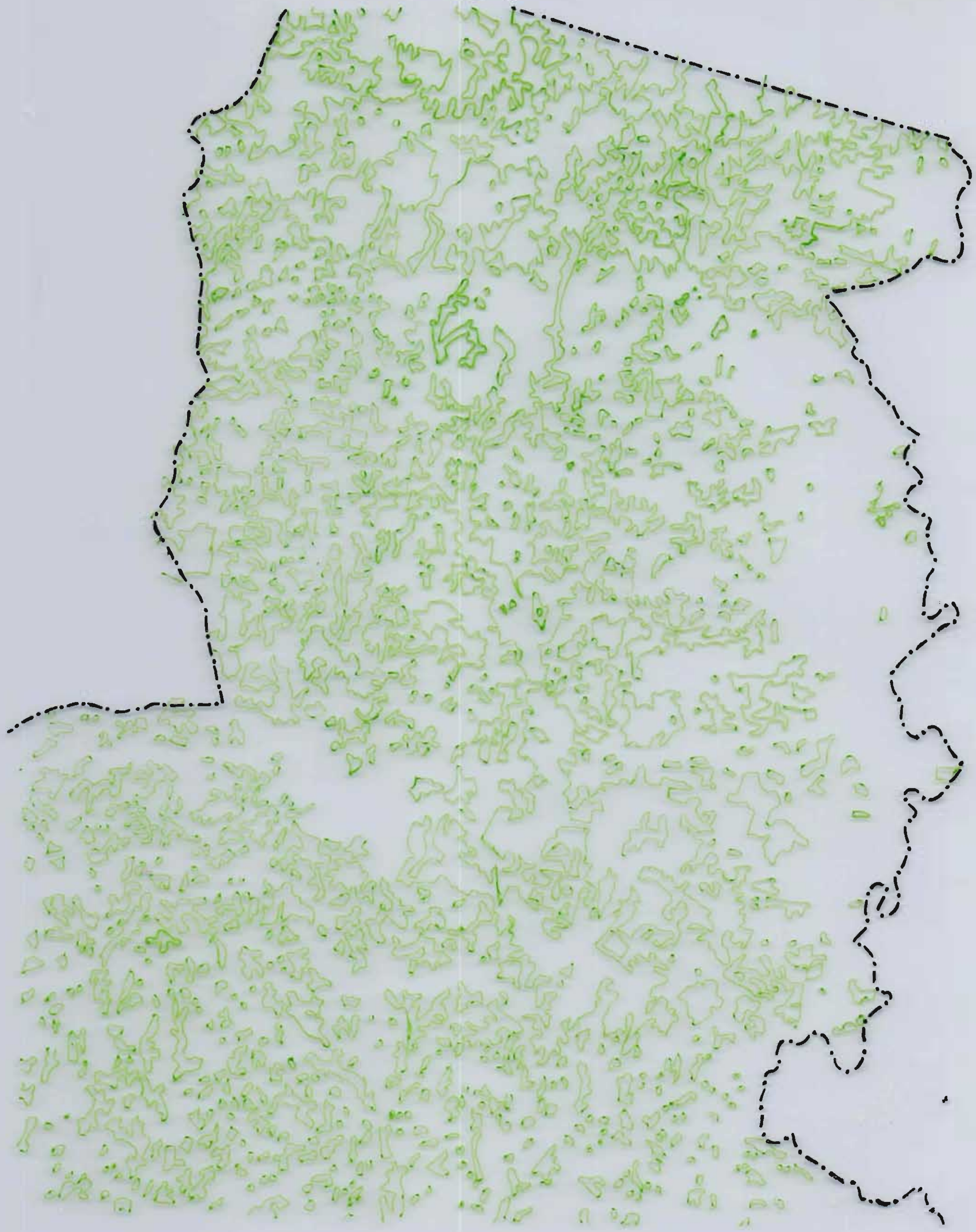

Figure 1. Areas Interpreted as Woodlands from Skylab-4 Photography.

Figure 2. Reproduction of the Skylab-4 photography
(approximate scale 1:318,066).

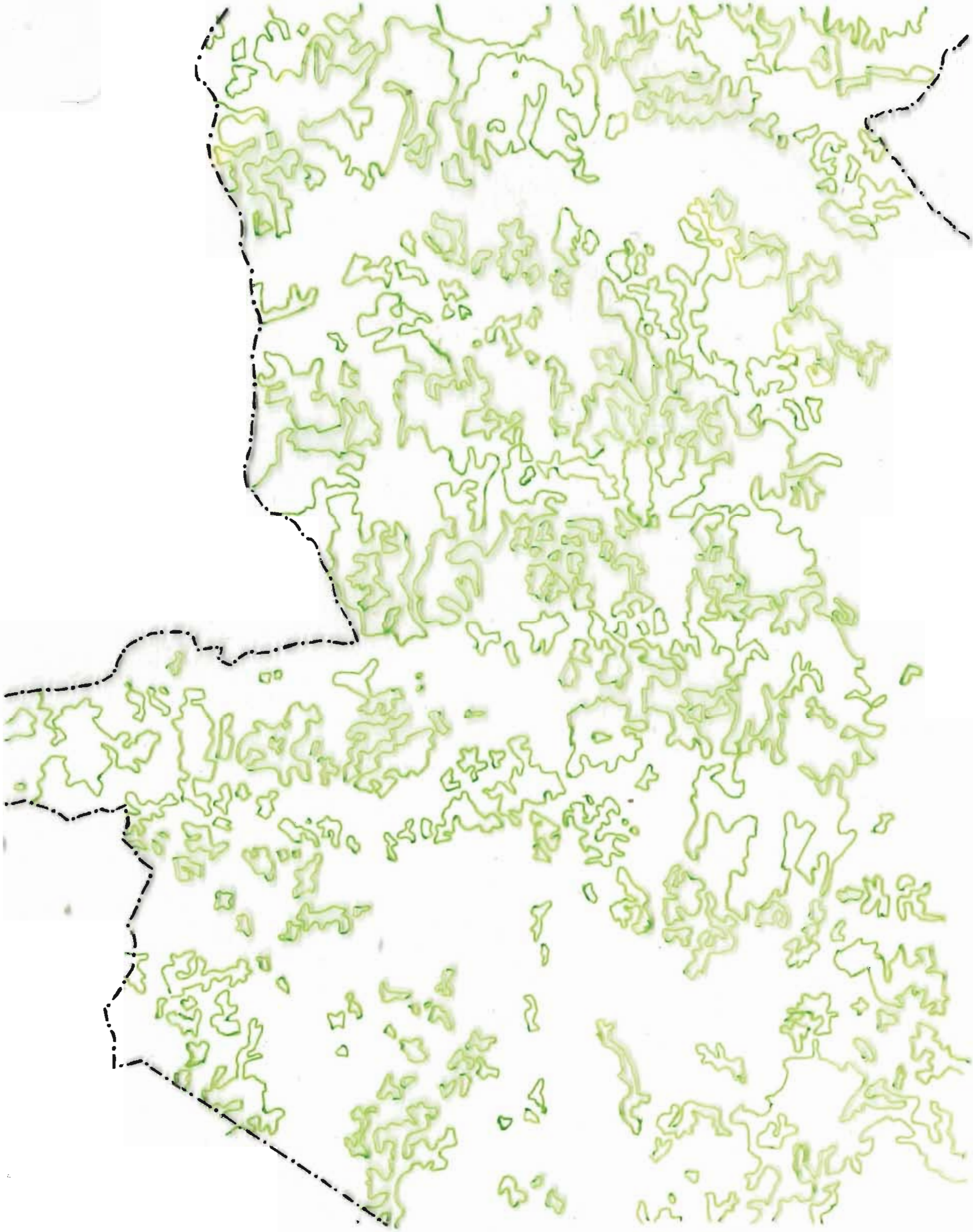

Figure 3. Areas Interpreted as Woodlands from LANDSAT-1 Color Composite.

Figure 4. Reproduction of the LANDSAT-1 color composite (approximate scale 1:291,715).

biases that might develop from the previous mapping of the same area. The delineation of woodland stands utilized the simplest form of interpretation using single photographs with no optical instruments to assist the author. The procedure for the interpretation was:

1. Acquiring the remotely sense data, from the EROS Data Center, Sioux Falls, South Dakota,
2. Overlaying each frame with a sheet of mylar,
3. Using the U.S. Geological Survey 1:250,000 Austin map sheet to establish the boundary of the study area thru the use of roads, streams, and other control points that could be located on both the remotely sensed data and the map, and
4. Delineating the woodland stands along their outside perimeter on each type of remotely sensed data.

The minimum size of woodland stands mapped was 50 acres.

Sample area

Land-use maps made from April, 1972, NASA high altitude 1:120,000 color infrared photography of the two counties were used to locate the woodland stands to be selected as sample areas. These stands had been mapped in 1972, and

1973, by graduate students in the School of Forestry, Stephen F. Austin State University, under a contract from the Johnson Space Center[4]. A total of 1,079 woodland areas was located and numbered on the land-use maps. From the total, 288 were selected randomly without replacement to be used as sample areas.

The sample areas were compared to the stands mapped from the Skylab-4 photography and the LANDSAT-1 imagery. By using features that could be located on both the remotely sensed data and the land-use maps, the sample areas were then checked to determine if they had been mapped from the remotely sensed data.

Crown closure estimation

Crown closure is defined as the portion of the area of a stand or other homogeneous unit covered by the crowns of trees (Spurr, 1960). Crown closure was selected as the measurement of stand density because tree crowns comprise the primary area that is sensed by the Skylab-4 photography and LANDSAT-1 imagery.

To accurately estimate crown closure, the interpreter must be experienced or have available a crown-density scale

[4]The detailed procedure for implementing this project is contained in a manuscript in press at the Johnson Space Center. It is co-authored by Dr. Robert D. Baker and Dr. David V. Smith, former members of the School of Forestry, Stephen F. Austin State University.

for use as a guide (Spurr, 1960). Crown closure estimation is subjective and can vary from one person to another. To estimate crown closure, the author relied upon his experience gained from working with aerial photographs.

Ocular estimates of crown closure for the 288 sample areas were made and categorized into 10 percent classes. These estimates were made from 1966 ASCS 1:20,000 black and white photography enlarged to the scale of 1:7,920. The crown closure classes in percent ranged from 1 - 10, 11 - 20, 21 - 30, ... , 91 - 100. The crown closure estimates were made from single photographs because stereo pairs were not available.

Ground truth

Because of the limitation of time and funds, 50 of the 288 sample areas were visited on the ground to determine the current stand conditions. Of the 50, all 19 plots grouped in the 61 - 70 percent crown closure class were visited because maximum accuracy for the LANDSAT-1 mapping was in this class. The remaining plots were selected to obtain a representative sample in the other crown closure classes. This was accomplished by stratifying these plots according to the percentage of the 288 samples in each crown closure class.

Each stand selected was located on the land-use maps and a 1:250,000 U.S. Geological Survey, Austin map sheet. The maps were used to locate roads which gave access to the stands.

RESULTS AND DISCUSSIONS

Data

The 288 sample stands which appeared on the land-use maps of Burleson and Washington counties were classified by the number mapped by crown closure classes for each of the space satellite systems (Table 1).

Statistical analysis

Analysis of the data collected was based upon the following assumptions:

1. Minimum area of a woodland stand consistently delineated was 50 acres.
2. The photointerpretation was completed by one individual.
3. The photointerpreter was familiar with woodland mapping procedures for this imagery.
4. Within each crown closure class the stands were homogeneous.

With these assumptions, the appropriate formula to determine the variance and standard deviation for each crown closure class was derived by J. P. Basu, Lockheed Electronics' Forestry Application, JSC. Percent accuracy was determined by dividing the number of correctly classified

Table 1. Woodland stands mapped or not mapped from Skylab-4 and LANDSAT-1 by crown closure classes.

CROWN CLOSURE CLASSES (Percent)	SKYLAB -4		LANDSAT-1	
	stands mapped	stands not mapped	stands mapped	stands not mapped
1-10	0	0	0	0
11-20	0	2	0	2
21-30	0	7	0	7
31-40	2	20	1	21
41-50	6	13	1	18
51-60	6	3	3	6
61-70	16	3	13	6
71-80	26	6	12	20
81-90	45	3	22	26
91-100	121	9	70	60
Total	222	66	122	166

stands mapped by the total number of stands in the crown closure class.

The formula for the variance is:

$$S^2 = \frac{1}{n_i} \sum_{i=1}^{n} (Y_i - \bar{Y})^2$$

where:

Y_i = the score of individual plots in the class under consideration. If the plot is mapped, the score of one is assigned; if the plot is not mapped, the score of zero is assigned.

$\bar{Y}$ = the number mapped divided by the number in the class.

n_i = the number of samples found in the class under consideration.

S^2 = variance

Discussion

Skylab-4 photography was superior to the LANDSAT-1 imagery for mapping woodlands. The better results from the Skylab-4 photography may be due to better resolution and contrast compared to the LANDSAT-1 imagery which had a data dropout (poor or nonexistent scan lines). The Skylab-4 photography was designed primarily for manual photo-interpretation while the LANDSAT-1 imagery was designed primarily for computer analysis. Even though the LANDSAT-1 imagery was designed for computer analysis, it has been interpreted by conventional methods because computer cost for data analysis is expensive.

Skylab-4 photography had a greater mapping accuracy in all classes above 35 percent. The optimum crown closure classes for woodland mapping were those above 61 percent (Table 2). The LANDSAT-1 imagery yielded a low mapping accuracy with a high of 68 percent in the 61 - 70 percent crown closure class. Field checking of the area showed that the stands mapped in this crown closure class had a dense understory of yaupon (*Ilex* sp.) which may have been influential in the results. The percent of woodland stands mapped from LANDSAT-1 imagery generally increased in accuracy from 55 percent crown closure class thru the 95 percent crown closure class. LANDSAT-1 imagery for mapping woodlands should probably be interpreted by computer.

The results of this study may be related to present land management needs in areas of similar forest types. For instance, the following woodland types are found in the counties in this study:

1. Post oak (*Q. stellata*) and black oak (*Q. velvutina*),
2. Chestnut oak (*Q. prinus*), and

Table 2. Percent accuracy of woodland delineation from Skylab-4 and LANDSAT-1 by crown closure classes.

CROWN CLOSURE CLASSES (Percent)	PERCENT CORRECT AND STANDARD DEVIATION SKYLAB-4	LANDSAT-1
1-10	*	*
11-20	0	0
21-30	0	0
31-40	9% ± 2.88%	5% ± 2.08%
41-50	32% ± 4.65%	5% ± 2.23%
51-60	67% ± 4.52%	33% ± 4.70%
61-70	84% ± 3.50%	68% ± 4.65%
71-80	81% ± 3.70%	36% ± 5.47%
81-90	94% ± 2.42%	46% ± 5.06%
91-100	93% ± 2.53%	54% ± 5.05%
1-100	77% ± 4.20%	42% ± 4.94%

* = No sample in the class.

3. Southern scrub oak, such as blackjack oak (*Q. marilandica*).

Even though the study was limited to one area, the results may be applied to the same species groups in other areas. Similarly, the procedure outlined in this study can be used to determine what crown density classes can be mapped from Skylab photography and LANDSAT-1 imagery in other forest types.

If a predictable relationship between crown closure and understory density exists, this study will be of importance to wildlife researchers. These professionals are capable of estimating the forage or mast per acre according to crown closure classes. Knowing the location of the woodland stands arrayed by crown closure classes will allow the wildlife research investigator to establish areas for sampling and gathering ground data to be used in wildlife habitat studies on extensive areas.

The potential for forest production in areas considered non-commercial is information essential to any long-range plan for meeting our needs in forest products, and alternative energy sources in the future.

CONCLUSIONS

Additional research is needed using LANDSAT-1 color composites of different bands taken in different seasons. The most useful LANDSAT-1 color composite is probably one made from Bands 4, 5, and 7, but the season in which the best woodland signature[5] can be obtained has not been determined. A study comparing different seasons composite is needed.

Another analysis of the LANDSAT-1 imagery would be to use the most suitable band from each season to produce a color composite that would enhance woodlands. By using different LANDSAT-1 color composites it may be possible to obtain a higher percent accuracy of the crown closure classes than that obtained in this study.

The use of computer compatible tapes[6] is another means of analysis for LANDSAT-1 data since the imagery is a secondary product. Better accuracy may be obtained by utilizing computer programs such as those available at

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[5]Signature is define as the spectral, tonal, or spatial characteristic that identify an object that is remotely sensed.

[6]Computer compatible tapes are the original format in which the data from LANDSAT-1 is transformed.

Texas A&M University, Purdue University, or Johnson Space Center.

With the seven different types of photographs available of the same area taken by the EREP, replication studies using these different media should prove fruitful. The photographs that hold the most promise are those taken by the Earth Terrain Camera. These photographs can be enlarged to a 1:125,000 scale with a smaller enlargement factor than the Multispectral Camera's 1:250,000 scale enlargement. Photographs taken with the Earth Terrain Camera should have better resolution and contrast. With the larger scale photographs, more detail could be mapped from this system, including more and smaller woodland stands which would permit a greater percent accuracy in the crown closure classes.

With the Multispectral Camera system, black and white photographs in 2 to 4 spectral bands can be used to produce a false color photograph by using one of the several commercial multichannel film viewers. Using these viewers, it is possible to vary the intensity of each black and white frame in the viewer to enhance the desired feature, or maximize the contrast between woodlands and other land uses.

Even though there are questions about the best imagery and methods for woodland delineation some possible uses of the study results are:

1. Multistage sampling for volume estimation.
2. Forest potential determination on a regional basis.
3. Multiple-use planning for forestry.

These are potential applications that are in the developing stages at the current time.

Multistage sampling for volume determination is based upon an assumed relationship between stand crown closure and stand volume. By establishing the percent accuracy mapped by crown closure, it will be possible to determine the optimum location of ground samples. The volume determined for the crown closure class can be multiplied by the number of stands expected in the class to estimate total volume in each class. The total volume for each class should give an estimate of total volume for a study area.

As previously stated, the potential for forest production in areas now considered non-commercial could be information invaluable to long-range planning for meeting regional and national goals.

In multiple-use planning for forests, one criterion for the plan can be based upon percent crown closure, as an indication of intensity of forest production. This knowledge can now be obtained quickly for areas of the

United States covered in the Skylab missions, but where information of this nature is not currently available from other sources.

While this study was only a small portion of the investigative needs of satellite imagery and photography, it has expanded the uses of this type of remotely sensed data in future forest inventory and production determinations.

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APPENDIX

PERCENT ACCURACY BY CROWN CLOSURE CLASSES OF WOODLAND STANDS
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ABSTRACT

LANDSAT-1 imagery and satellite photography have been utilized for land-use mapping. This study investigated the correlation between woodland stands mapped and their percent crown closure using LANDSAT-1 imagery and Skylab-4 photography. On the basis of percent accuracy of crown closure classes mapped or not mapped, Skylab-4 photography proved superior over LANDSAT-1 imagery for mapping woodlands.

VITA

Roger Goldsmith was born in Houston, Texas, on July 30, 1950, the son of Rachel Gray Goldsmith and Jasper L. Goldsmith. After graduating from Furr High School, Houston, Texas, in 1969, he entered Stephen F. Austin State University. He received the degree of Bachelor of Science in Forestry from Stephen F. Austin State University in May, 1973, at which time he was commissioned Second Lieutenant in the United States Army Reserve. In June, 1973, he entered the Graduate School at Stephen F. Austin State University.

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